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1967

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1967 No. 4

The Food of the Dogfish, *Squalus acanthias* L.

By BENNET B. RAE
Marine Laboratory, Aberdeen
April, 1967

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CONTENTS

INTRODUCTION 3

MATERIAL 3

EXAMINATION OF THE STOMACH CONTENTS

Proportion of Fish with Empty Stomachs 5
Composition of the Food 8

PREVIOUS INVESTIGATIONS OF DOGFISH FOOD

North Sea and Adjacent Grounds 9
Western Atlantic 10
Pacific Ocean 10

DISCUSSION 11

SUMMARY 15

REFERENCES 15

APPENDIX: Review of Evidence from Commercial Fishing 17

The Food of the Dogfish

Squalus acanthias L.

INTRODUCTION

Before the second great war the common or piked dogfish or spurdog, *Squalus acanthias* L., was of minor importance in Scottish fisheries and indeed detailed returns of this species were published in the Scottish Sea Fisheries Statistical Tables for the first time in 1954, when 22,689 cwt were landed in Scotland by British vessels. Since that year the annual catch has increased, with some fluctuations, to a maximum of 98,565 cwt in 1966. This increase does not indicate any natural increase in the stocks, nor does it necessarily reflect any increased effort to catch this fish. In fact it represents an improvement in the demand for dogfish and the response by the fishermen to its improved market value. Between the wars large quantities of dogfish taken by Scottish trawlers were thrown overboard as it was unprofitable to bring them ashore. Moreover, the appearance of dogfish on fishing grounds frequently resulted in fishermen changing grounds in order to avoid these fish which at that time were regarded as a nuisance because of the disruption they were believed to cause to shoals of more desirable fish and because of the harmful effect they produce, while in the cod-end, on the appearance of good quality fish.

The dogfish, however, has long been regarded with more favour in England and Wales than in Scotland. On the English market the average price per cwt has risen steadily from 12s 5d in 1938 to 24s 7d in 1946 and finally to 54s in 1965. In Scotland this fish attained its highest-ever average value of 39s 2d in 1966. It is not surprising, therefore, that landings in England and Wales have exceeded those in Scotland, even though the chief dogfish grounds are located off the north and west coasts of Scotland.

In recent years, however, the English catch of dogfish has shown a marked decline. From an annual average of 157,000 cwt over the period 1956 to 1960, landings have fallen to around 89,000 cwt for the years 1961 to 1965. This decline, by about 45%, has given rise to some concern (Aasen, 1964; Holden, 1966 a) and although the average Scottish landings in the same periods rose from 63,000 cwt to 70,000 cwt, this cannot be regarded as encouraging, since with the improved market value for dogfish Scottish fishermen are probably now bringing ashore a greater proportion of their catch of this fish than formerly. Anxiety about the declining landings has naturally focussed the attention of fisheries scientists on the life history and biology of the dogfish and already some research has been devoted to its age and growth and to its migrations. Its food and its predatory habits on stocks of other species of greater commercial importance have also aroused considerable interest, partly perhaps because of the views of fishermen on this subject. For this reason it was decided to examine Scottish research records of dogfish food and any available evidence of the predatory habits of the species.

MATERIAL

Between the two wars routine observations on board Scottish research ships included an examination of the stomach contents of most of the species caught during the sampling of fish stocks with the otter trawl. Dogfishes were included in this survey and from 1921 to 1939 several thousands were examined. Unfortunately the numbers examined from each haul were not always recorded, nor were the numbers of stomachs containing unrecognisable food noted, the emphasis during this period being laid on the identification of the various food items. Recognisable food was recorded in 942 stomachs.

After an interruption owing to the second war the examination of the stomach contents of dogfish was resumed in 1949. A few years later these observations were extended to include a study of the food of all

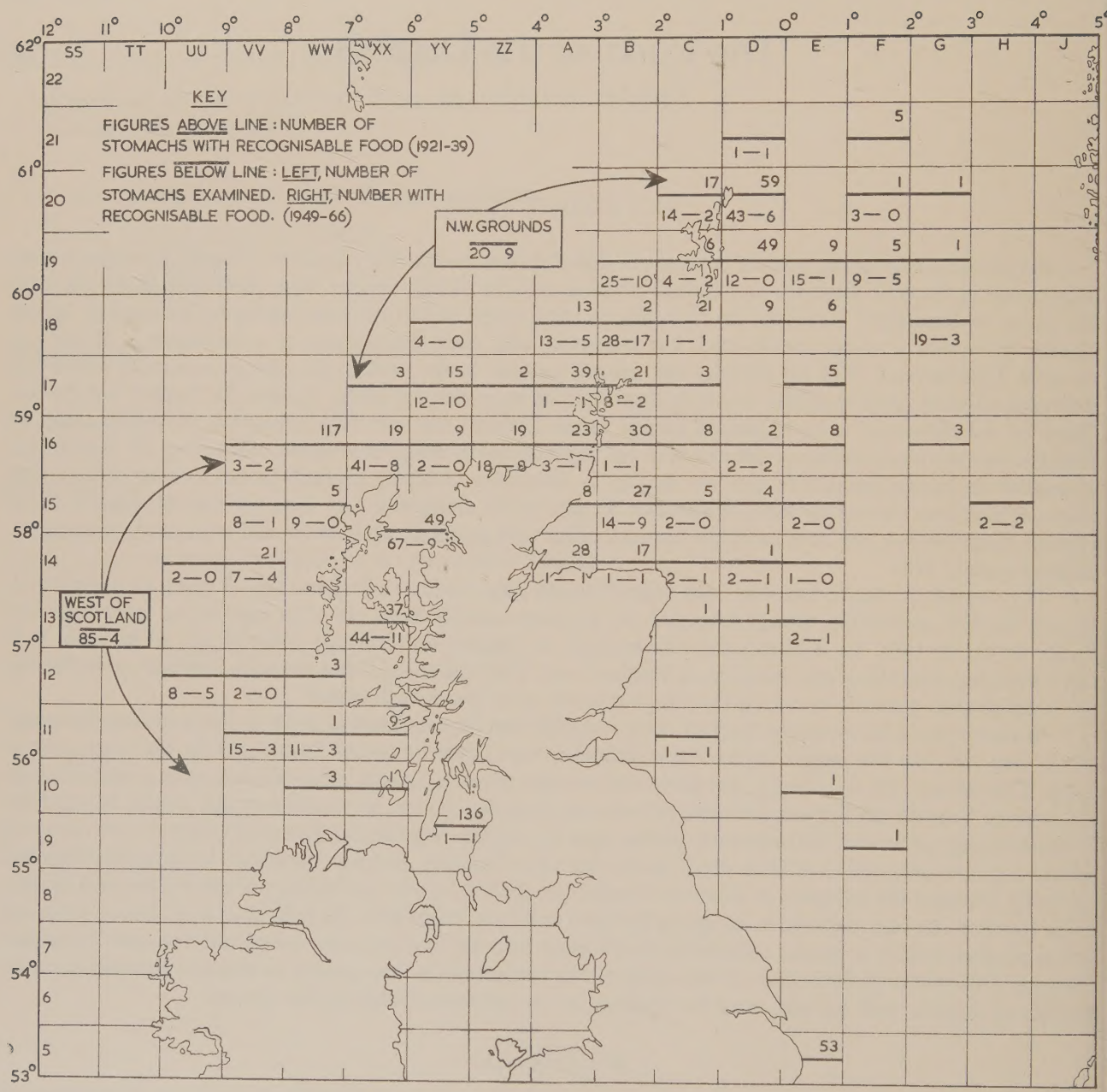
KEY
FIGURES ABOVE LINE : NUMBER OF STOMACHS WITH RECOGNISABLE FOOD (1921-39)
FIGURES BELOW LINE : LEFT, NUMBER OF STOMACHS EXAMINED. RIGHT, NUMBER WITH RECOGNISABLE FOOD. (1949-66)
N.W. GROUNDS 20 9
WEST OF SCOTLAND 85-4
SS TT UU VV WW XX YY ZZ A B C D E F G H J
12° 11° 10° 9° 8° 7° 6° 5° 4° 3° 2° 1° 0° 1° 2° 3° 4° 5°
62° 61° 60° 59° 58° 57° 56° 55° 54° 53°

Fig. 1. Sampling of dogfish stomachs.

elasmobranchs in conjunction with an analysis of the vitamin A, carotenoids and total lipids in the livers of these fish by the late Dr L. R. Fisher (1964). In these later investigations the numbers of empty stomachs were recorded, along with the numbers containing food, both recognisable and unrecognisable. In this period most of the fish were, as before, examined at sea, but small numbers were preserved and dealt with in the laboratory. A number of dogfish tagged by Norwegian and English scientists and recaptured by Scottish fishermen and examined at the Marine Laboratory have also been utilised in this study. Since the second war 634 dogfish have been examined, of which 256 contained food, including 180 with recognisable food.

Squalus acanthias occurs widely, though irregularly, over almost the entire North Sea and west of Scotland grounds. The main concentrations of these fish, however, are located off the north and west coasts of Scotland, including grounds to the west, north and east of Shetland, and it is from these areas that shoals of this fish invade the northern half of the North Sea every summer. Evidence of the distribution and movements of the fish, probably variable from year to year, has been derived from a study of dogfish catches per unit of fishing time by British trawlers over the years 1947 to 1957 (Rae, 1961) and from tagging experiments on northern and north-western grounds (Aasen, 1964; Holden, 1965). Dogfish tagged and liberated to the west of Orkney and Shetland, for example, have subsequently been recaptured within the North Sea in the latitude of Aberdeenshire, and in at least one instance as far south as Berwick Bank (latitude 56°N). Although some very large catches of dogfish are taken from time to time by Scottish research vessels, sampling of the stomach contents has generally been on a modest scale throughout, as other routine duties have permitted. The sampling over the entire period may, therefore, be regarded as truly random in character. Although most of the records were collected from March to October stomachs were examined and food identified in each month from February to December in the years 1921–1939 and in each month throughout the entire year in the period 1949 to 1966. Figure 1, giving the numbers of dogfish containing recognisable food from 1921 to 1939 and the numbers examined, together with those containing recognisable food, from 1949 to 1966, shows that the stomach sampling was reasonably representative of the whole area of distribution.

EXAMINATION OF THE STOMACH CONTENTS

The results of the examination of the stomach contents are summarised in Table I. Because of the difference in time of the two sets of observations the analysis are given separately, for comparative purposes, and combined. The dogfish in each period ranged from 30 to 110 cm in length but most of them fell within the 51 to 90 cm size-group. In view of the general similarity in the food of dogfish of all sizes and of the relative scarcity of fish in the lower half of the size-range, no attempt has been made to study possible differences in the food on a size-group basis.

Proportion of Fish with Empty Stomachs

Although it was impossible on the strength of the available data to calculate the percentage of empty stomachs observed during the earlier investigations from 1921 to 1939, it is evident from the observers' notes that the proportion was high, probably from 50 to 75%. From 1949 to 1966, 378 (60%) of the stomachs contained no food. These high proportions are in agreement with the results of others who have studied the food of this dogfish. For example, Todd (1905, 1907) found 24 to 67% empty, Templeman (1944) 57% empty, Chatwin and Forrester (1953) 8 to 49% empty, Bonham (1954) 41% empty, and Holden (1966 b) 60 to 73% empty. In both periods the numbers of empty stomachs varied considerably from one sample to another and not infrequently none of the stomachs in individual samples was found to contain food.

The numbers of empty stomachs among dogfish are, in the experience of the author, considerably higher than in any other fish examined in Scottish waters. In the cod, for example, the monthly proportions of empty stomachs ranged from 12 to 24% with an average of 16% over the whole year (Rae, 1967). In certain flatfishes the seasonal variation is much greater. For example, in the lemon sole (Rae, 1956) the monthly variation of empty stomachs ranged from 4 to 97%, giving an average of 29% throughout the year. Dogfish with little or no food in their stomachs have been obtained at all times of the year, including the summer months when other species of fish normally are feeding most actively.

The numbers of dogfish stomachs containing food in each month in the present investigations are given in Table II. The calculation of the percentages of feeding fish is, of course, possible only in the years 1949–1966. These show considerable fluctuations in the proportions of feeding fish throughout the year; more than half contained food in February, April, June, July and October, while only 33% to 8% were feeding in the remaining months. Apart perhaps from the fairly high proportion of feeding fish in June and July there is little evidence from the Scottish data of any significant seasonal variations in feeding in dogfish.

The only results in any way comparable are those from ling and tusk caught in deep water, but the numbers of these fish examined so far are insufficient to provide a satisfactory comparison. It seems clear that both ling and tusk, as well as some other species, regurgitate their food when being hauled to the surface in deep water, and it is possible that dogfish do likewise. Holden (1966 b) discusses other likely causes of the higher proportion of empty stomachs but no very conclusive explanation has yet been suggested. Further investigation of the overall preponderance of empty stomachs in dogfish and their seasonal feeding activity would seem desirable.

TABLE I

THE FOOD OF DOGFISH, *Squalus acanthias* L., IN THE NORTH SEA AND ON THE WEST OF SCOTLAND

Years	1921–1939		1949–1966		1921–1966	
Months	II–XII		I–XII		I–XII	
No. examined	?		634			
No. empty	?		378	=60%		
No. containing food	?		256	=40%		
No. with unrecognisable food	?		81	=13%		
No. with recognisable food	942		180	=28%	1,122	
No. containing:—		%		%		%
PISCES	705	75	147	82	852	76
Herring, *Clupea harengus* L.	288	30	19	11	307	27
Sprat, *Clupea sprattus* L.	4	+	—	—	4	+
Clupeoids, *Clupea* sp.	—	—	6	3	6	1
Mackerel, *Scomber scombrus* L.	33	4	15	8	48	4
Sand eels, *Ammodytes* spp.	74	8	17	9	91	8
Gadoids, *Gadus* sp.	—	—	17	9	17	2
Haddock, *Gadus aeglefinus* L.	8	1	3	2	11	1
Whiting, *Gadus merlangus* L.	18	2	12	7	30	3
Norway pout, *Gadus esmarkii* Nilsson	8	1	6	3	14	1
Blue whiting, *Gadus poutassou* (Risso)	3	+	—	—	3	+
Hake, *Merluccius merluccius* (L.)	1	+	1	1	2	+
Three-bearded rockling, *Onos tricirratus* (Bloch)	1	+	—	—	1	+
Flatfishes ? genus	—	—	1	1	1	+
Lemon Sole, *Microstomus kitt* (Walbaum)	—	—	2	1	2	+
Long rough dab, *Hippoglossoides platessoides* (Fabricius)	3	+	2	1	5	+
Common dab, *Limanda limanda* (L.)	2	+	—	—	2	+
Dragonet, *Callionymus lyra* L.	3	+	3	2	6	1
Argentine, *Argentina* sp.	—	—	1	1	1	+
Gurnard, *Trigla gurnardus* L.	1	+	—	—	1	+
Angler, *Lophius piscatorius* L.	1	+	—	—	1	+
Armed bull-head, *Agonus cataphractus* (L.)	1	+	—	—	1	+
Sea snail, *Liparis* sp.	1	+	—	—	1	+
CRUSTACEA	109	12	15	8	124	11
Decapoda ? genus	3	+	2	1	5	+
Hermit crabs, Eupaguridae	15	2	1	1	16	1
Swimming crab, *Portunus* sp.	—	—	1	1	1	+
Circular crab, *Atelecyclus* sp.	—	—	1	1	1	+
Long-armed Munida, *Munida* sp.	2	+	—	—	2	+
Norway lobster, *Nephrops norvegicus* (L.)	1	+	1	1	2	+

TABLE I (continued)

Shrimps, *Crangon* sp.	5	1	2	1	7	1
Pandalus sp.	4	+	3	2	7	1
Pasiphaea sivado Risso	1	+	—	—	1	+
Unidentified	18	2	—	—	18	2
Euphausiids, *Meganyctiphanes norvegica* (M. Sars)	58	6	—	—	58	5
Unidentified	—	—	1	1	1	+
MOLLUSCA	108	11	18	10	126	11
Cephalopoda	88	9	17	9	105	9
Squid, *Loligo* sp.	21	2	3	2	24	2
Octopods, *Eledone cirrhosa* (Lamarck)	38	4	2	1	40	3
Sepiola sp.	13	1	4	2	17	2
Rossia sp.	—	—	1	1	1	+
Gasteropoda	—	—	1	1	1	+
Whelk, *Buccinium* sp.	—	—	1	1	1	+
ANNELIDA	3	+	—	—	3	+
COELENTERATA	11	1	—	—	11	1
Jellyfish, *Chrysaora* sp.	8	1	—	—	8	1
Anemones, Anthozoa	3	+	—	—	3	+
CTENOPHORA	35	4	9	5	44	4
Pleurobrachia sp.	35	4	9	5	44	4
TUNICATA	—	—	11	6	11	1
Salps, *Salpa* sp.	—	—	10	6	10	1
MAMMALIA	—	—	1	1	1	+

TABLE II

MONTHLY FEEDING OF DOGFISH

	1921–1939	1949–1966		
Months/Years	No. feeding	No. examined	No. feeding	%
January	—	15	3	20
February	10	6	4	67
March	31	29	8	28
April	64	5	3	60
May	54	8	1	13
June	97	138	90	65
July	131	3	2	67
August	305	40	13	33
September	119	45	12	27
October	97	27	15	56
November	26	199	66	33
December	8	12	1	8
Totals	942	527	218	41

Note: The totals examined and containing food for 1949 to 1966 are less than in Table I as the months of capture of some of the fish are not known precisely.

In this connection it is noteworthy that many of the stomachs classified as empty in these Scottish investigations were in fact found to contain water. Occasionally, too, stomachs with traces of food contained a quantity of water in which the traces, usually of unrecognisable material, were floating. Of the other investigators of dogfish food, Todd (1907) refers to the presence of water in the stomachs thus—"In the majority of cases in which *Acanthias* (*Squalus*) had been feeding on *Pleurobracheus* and in some cases in which no food was found, the stomachs were distended with water", and more recently Bonham (1954) and Jensen (1966) mention the occurrence of a "clear fluid" in some stomachs.

Composition of the Food

From 1921 to 1939, 942 stomachs out of several thousands examined contained recognisable food. In the second period, 1949–1966, 256 (40% of the number examined) contained food, but of these only 180 (28% of the total examined) contained recognisable food; 81 stomachs (13%) contained unrecognisable food along with, in a few instances, some identifiable matter.

The frequency with which the various food items occurred in the stomachs (Table I) is expressed as percentages of the total numbers containing recognisable food. It is evident that the food of this dogfish includes a considerable variety of organisms, but fish of one kind or another occurred in at least 75% of the stomachs and must therefore be regarded as the principal food type. Crustaceans and molluscs were each eaten by 8 to 12% of the fish, while annelids, coelenterates, ctenophores, and tunicates were taken less frequently and apparently somewhat more spasmodically. The single record of mammalian flesh, possibly porpoise, in one stomach is interesting since it may indicate a scavenging habit in dogfish feeding.

In view of the "residual" nature of much of the food in the dogfish stomachs no volumetric measurement of the contents or of the individual food types was attempted. However, because of (1) the greater size of the fish compared with the size of many of the invertebrates eaten, (2) the fact that the fish were more often ingested in the form of bites than swallowed whole and (3) the relatively small numbers of most of the invertebrates found in the individual stomachs, it would appear that the importance of fish as food may be even greater than the frequency of their occurrence in the stomachs (75%) suggests.

Table I lists at least 19 different species of fish, including pelagic and demersal types, in the food over the entire period of the investigations. In the inter-war years herring were identified in 30% of the stomachs and were thus the outstanding single species in the food. In this period sand eels came next in importance, but in only 8% of the stomachs, while mackerel and gadoids each occurred in 4%.

The food during the years 1949–1966, while consisting on the whole of the same species as between the wars, nevertheless reveals some noticeable changes in the proportions of the various types eaten. The most obvious of these is the marked fall from 30 to 11% in the proportion of dogfish feeding on herring and while predation on sand eels remains at about the same level the numbers eating mackerel and gadoids increased appreciably, gadoids being found in over 20% as compared with 5% between the wars.

In each period, pelagic types, including herring, mackerel, sand eels and sprats, and to a less extent semi-pelagic types such as whiting, *Gadus esmarkii*, *G. poutassou* and hake preponderated in the food, thus appearing to indicate a pronounced pelagic feeding habit in this dogfish. Yet the occurrence of benthic feeders like the haddock and the various flatfishes in the stomachs suggests that *Squalus* also feeds demersally at certain times, as is confirmed by the capture of considerable quantities of this dogfish by seine and otter trawl.

The crustacean prey consists of a variety of decapods and euphausiids, the latter being particularly prominent in the Firth of Clyde between the two wars. The molluscan food throughout these investigations is represented almost entirely by cephalopods, of which four genera have been identified.

The pelagic feeding habit of *Squalus*, demonstrated so clearly by the types of fish it preys upon, is also evident in the pelagic or semi-pelagic character of some of its crustacean and molluscan food. Its predation on purely planktonic types, such as salps, ctenophores and coelenterates, is even more remarkable. As already indicated, the occurrence of planktonic organisms in the dogfish stomachs in Scottish waters would appear to be somewhat spasmodic, but this may be partly an artifact arising from the rapid disintegration of the tissues of some of those organisms under the influence of the gastric fluids. In other words, such planktonic types probably remain identifiable for only a short time and, unless the stomach contents are examined almost immediately the food has been ingested, recognition of the various types may be impossible.

At this point it seems appropriate to refer to the number of stomachs (81 or 13% of the number examined) containing food which was not identified. This represents a greater proportion of unrecognisable food material than has been experienced by the author in the stomachs of any other species examined from Scottish waters. In view of the complete absence from these stomachs of the otoliths, or other bones of fish, chitinous claws of crustaceans, jaws of cephalopods and polychaete setae, it seems improbable that the unrecognisable material was derived from organisms in any of these four groups. It seems reasonable, therefore, to assume that the unrecognisable material has resulted, largely at any rate, from the breakdown of readily digestible food in the stomachs, and that the most likely items in this category are the planktonic types such as salps, ctenophores and coelenterates. If this is so the planktonic types obviously represent a rather more important source of dogfish food than their frequency of occurrence in Table I would indicate. Jensen's (1966) reference to a "light-gray, custard-like material", which he regarded as well digested food, in some dogfish stomachs, suitably describes some of the unrecognisable food found in the Scottish studies.

PREVIOUS INVESTIGATIONS OF DOGFISH FOOD

In view of the relatively small number of dogfish stomachs containing food in these Scottish investigations it is worth considering the results obtained by others who have studied the food of this fish.

North Sea and Adjacent Grounds

In his comprehensive studies of the food of fishes in the southern North Sea, Todd (1905, 1907) examined 180 *Acanthias vulgaris* (= *Squalus acanthias*) from March to October. Of these 110 contained recognisable food, including *Pleurobracheus* (*Pleurobrachia*) *pileus* in 54%, fish in 30%, crustaceans in 26%, gephyreans (*Echiurus*) in 15%, molluscs in 4% and polychaetes in 2%. The crustaceans eaten were mainly *Crangon vulgaris, Pandalus montagui* and *Eupagurus bernhardus*. The fish in the dogfish's menu included *Solea vulgaris, S. lutea, Clupea harengus, C. sprattus, Gadus merlangus, Pleuronectes platessa, Gobius minutus, Trachinus draco* and *Petromyzon,* but none of these appeared to have been eaten frequently or in any quantity. Clearly the outstanding single item in this area was *Pleurobrachia* but it is perhaps worth noting that most of the dogfish preying on this organism were taken in a single sample in which 52 fish were feeding (that is, nearly half of Todd's total containing recognisable food) in June, at a time when *Pleurobrachia* reaches its first density peak in the plankton.

From November 1919 to January 1920 Ford (1921) collected stomachs from dogfishes landed at Plymouth and caught, presumably, at the western end of the English Channel. Of the 143 containing recognisable food, 137 contained the remains of fish, six contained crustacean remains and three molluscan remains. The fish eaten included herring and pilchards (*Clupea pilchardus*) in 67% of the stomachs, mackerel in 19%, gadoids (*Gadus merlangus, G. luscus, G. minutus*) in 4%, and *Pleuronectes* sp., *Trigla* spp., *Callionymus lyra* and *Raia* sp. each in 1·4%. Ford pointed out that his examination of the food coincided with the local fisheries for herring, pilchard and mackerel so that this may have accounted for the high proportions of these fish in the stomachs. The dogfish examined included fish of 36–50 cm, some of which had been eating herring, mackerel and *Callionymus,* from which Ford concluded that the food of the smaller dogfish was not significantly different from that of the bigger fish.

Holden (1966 b) examined the stomachs of 955 spur-dogs (size-range 26–108 cm) from North of Scotland grounds, and 125 (76–101 cm) from "eastern coastal North Sea grounds". Food was found in 256 and 48 of the stomachs, respectively, and of these 107 and 16 contained unidentifiable material. Holden's analysis of the stomach contents revealed a considerable variety of organisms in the food, including fish, molluscs, crustaceans, annelids, coelenterates and several miscellaneous items. Fish formed the bulk of the food, however, and included at least eleven different species from the grounds to the North of Scotland and seven from the North Sea. Off the north of Scotland sand eels proved to be the commonest food type and were identified in 42% of the stomachs; herring occurred in 13%, gadoids in 12% and mackerel in 3%; among the invertebrates, squid were found in 9%. In the relatively small number of dogfish examined from the North Sea Holden found decapod crustaceans in 23% of the stomachs containing recognisable food and sand eels in 16%,

dragonets (*Callionymus*) in 13%, flatfishes and gadoids each in about 16% and herring in only 3%. The stomachs from the north of Scotland contained a number of miscellaneous items including possibly one with porpoise and another with seal flesh.

Western Atlantic

Templeman (1944) examined the stomachs of 1,171 dogfishes, *Squalus acanthias*, caught by hand- and long-line off Newfoundland from August to November. As many as 57% of these stomachs were empty, and the analysis was further complicated by about 30% containing only bait in the form of herring, mackerel, pieces of cod and embryos of dogfishes, thus giving a total of 87% devoid of food except for bait. The 139 stomachs containing recognisable food included 80 (58%) with fish, 64 (46%) with crustaceans including 60 (43%) with amphipods, two with molluscs (squid and whelk), two with polychaetes, eleven (8%) with coelenterates and seven with "oddities" and various seaweeds. Of the dogfish feeding on fish, 20 (14% of those containing recognisable food) had preyed on herring, seven (5%) on capelin, seven on cod and one on blenny. Although the 60 dogfish feeding on amphipods seemed to suggest a considerable predation on these crustaceans, each stomach contained only from one to five individuals, so that these relatively small animals did not represent any appreciable quantity of food. It would seem that the herring was the most numerous single species in the food. At the same time in a rapid examination of stomachs from inshore grounds in July, Templeman found dogfish feeding almost exclusively on capelin. In a sample of 24 dogfish all had been feeding on capelin and only one on herring.

Off the north-eastern United States, investigators have found dogfish feeding on a variety of fish and invertebrates including mackerel, haddock, herring, silver hake (*Merluccius bilinearis*), squirrel hake (*Urophycis chuss*), winter flounder (*Pseudopleuronectes americanus*), amphipods, shrimps, crabs, squid, worms and ctenophores (Jensen, 1966).

Pacific Ocean

Squalus acanthias also occurs on the Pacific coast of North America where it is also known as *Squalus suckleyi*. Fraser (1946) referred to an abundance of records of the stomach contents of dogfish, nearly all of which were obtained during a study of the Pacific herring (*Clupea pallasii*). With two exceptions all the dogfish containing recognisable food had eaten herring. One of the two exceptions had eaten euphausiids and the other a small octopus. Fraser also found dogfish feeding on offal around the wharves of canneries on the coast of British Columbia.

Clemens and Wilby (1946) stated—"The dog-fish feeds upon practically all of the smaller fishes, especially herring, pilchards, anchovies, smelts, sand-lances, and occasionally young dog-fish, squid, as well as pelagic crustaceans when they occur in large numbers. It is also a scavenger feeding upon offal from fish canneries and reduction plants and refuse dumped at sea."

Chatwin and Forrester (1953) examined nearly 2,000 dogfishes from different localities on the coast of British Columbia. All of the 229 fish with food in their stomachs in one sample of 249 caught at the mouth of the Fraser river on 12th and 13th May, 1953, had been eating eulachon (*Thaleichthys pacificus*), a member of the smelt family which enters the river to spawn in the spring. Smaller numbers of dogfish from outside the river mouth about the same time in 1950 and 1953 also revealed eulachon as the commonest single species in the food (in 23% and 92% of the stomachs respectively), although invertebrates as a group were also eaten fairly frequently, by 59% and 29% of the dogfishes. However, these results would seem to overstress the importance of this species as dogfish food on the coast as a whole, as samples from other coastal localities, covering all periods of the year from 1944 onwards, revealed not more than 2·0% of the dogfish feeding on eulachon. The food in these latter areas varied considerably. On the west coast of Vancouver Island more than half of the stomachs contained shrimps and less than 25% contained fish. In Hecate Strait more than 60% of the dogfishes had been feeding on fish, including 26% on flatfishes, and only 15% on shrimps. In the Strait of Georgia rather more than 60% had eaten fish, including 21% on herring (*Clupea pallasii*), 10% on hake and 16% on shrimps. In these three localities the proportions preying on herring varied from 3 to 21%, and on sand eels from 2 to 5%. In each of the three samples unidentified material occurred in 13 to 25% of the stomachs.

Bonham (1954) analysed the stomach contents of more than 1,100 *Squalus acanthias* caught at 24 stations off the coast of Washington State from 1941 to 1943. In addition to noting the frequency of occurrence of the various food items in the stomachs, Bonham also measured the volumes of each type. Fish constituted two-thirds of the food; crustaceans and molluscs contributed appreciable quantities, while annelids, coelenterates, echinoderms, sponges and seaweed were eaten less frequently or on rare occasions. The most prominent items—ratfish (*Hydrolagus colliei*—20% of the total volume of food), herring (*Clupea pallasii*—18%), and euphausiids (9%)—together formed slightly less than half of the total. It is noteworthy that these three types occurred in 8%, 20% and 23%, respectively, of the stomachs containing food.

Bonham also recorded 116 dogfish taken from a herring trap as feeding almost exclusively on herring, as might be expected, but the amount of food in these stomachs was not appreciably different from the amount in dogfish caught elsewhere.

In Japanese waters Sato (1935) examined 128 dogfish in June and July, of which 60 had preyed on fish and 21 on various invertebrates. The fish included sardines (*Sardinia melanosticta*—the major item—in 48 stomachs), herring (*Clupea pallasii*), Pacific salmon (*Oncorhynchus keta*) and Pacific cod (*Gadus macrocephalus*).

DISCUSSION

These studies of the food cover a very wide area of the spurdog's distribution, although some of the investigations obviously were carried out on local stocks and others on a seasonal basis. In British waters Todd examined dogfish from the relatively shallow southern North Sea, which must be regarded as a marginal area for this species. Moreover, his high proportion feeding on *Pleurobracheus pileus* was derived from one large sample examined in June about the time this organism reaches its spring maximum. This somewhat seasonal effect would appear to overstress the importance of *Pleurobracheus* in the dogfish's food. Similarly, Ford obtained his records in the winter from dogfish caught during a fishery for herring and pilchards, and for this reason he indicated the danger of attaching too much importance to his results. Although Holden examined many more fish than either Todd or Ford, all his northern samples were obtained from grounds to the north of Scotland, presumably from Orkney westwards to the longitude of the Butt of Lewis. Holden found that sand eels, in 42% of the stomachs, constituted the major food of the dogfish in this area. He also regarded his sampling as representative of the Scottish-Norwegian stock of dogfish and concluded that sand eels, not herring as indicated by others (e.g. Rae, 1961), form the outstanding item in the food of the spurdog.

However, in view of the wide distribution of this dogfish in the North Sea and western grounds (see Fig. 1) and having regard to the variety of ecological conditions the species occupies in Scottish waters, it is doubtful if Holden is justified in assuming that his results are representative of the food of the Scottish-Norwegian dogfish stock. Moreover, although his analysis of the food is probably correct in showing 42% feeding on sand eels, it should be pointed out that grounds to the north of Scotland are particularly rich in sand eels. This is evident from Scottish research vessel records and even more so from an analysis of the stomach contents of various species of fish common in that area. In a paper on the food of cod (Rae, 1967) for example, the author has shown that over the entire year sand eels may be eaten by anything up to 85% of the cod, depending on the particular locality and the time of year. Cod eat sand eels in this area throughout the entire year, but this predation is greatest during the summer when the shoals of sand eels are most dense and when they may be present in the stomachs of all the fish in certain cod samples.

Although Holden mentions that one of his samples was obtained over "a period exceeding one year" he gives little information about the others and no indication of the years or the months in which his samples were procured. For comparison with his results it is interesting to study the Scottish records from north of Scotland grounds within the area bounded by latitudes 58°30′N and 60°00′N and longitudes 3°W and 6°W. These are given in Table III which shows that from 1921 to 1939 herrings were the most prominent food of the dogfish, in 27% of the stomachs, with sand eels next in importance, in 15%. From 1949 to 1966, however, gadoids were the commonest item, in 16%, with sand eels again second in 10% and herring in only 5%. Table III thus indicates a change in the dogfish food off the north of Scotland from one period to the other. No comparable change in the diet of dogfish is discernible in the data available from other Scottish regions, and there is no evidence to suggest that herring is preyed upon less frequently in these regions than formerly.

Dogfish with recognisable food in their stomachs were examined in each month from February to Decem-

TABLE III

MAIN FISH CONSTITUENTS OF SPURDOG FOOD OFF THE NORTH OF SCOTLAND

Period	Months	No. with recognisable food	No. feeding on:— Herring	Sand eels	Mackerel	Gadoids
1921–1939	II–XII	141	38	21	3	9
		%	27	15	2	6
1949–1966	I–XII	58	3	6	2	9
		%	5	10	3	16
1921–1966	I–XII	199	41	27	5	18
		%	21	14	3	9

ber in the first period, when most of the stomachs were obtained from March to October with peak sampling in August, and from January to December in the second, in which sampling was heaviest from June to November with peak sampling in these two months (Table II). Despite the preponderance of sampling during the summer, when sand eels are most abundant, the proportions of spurdogs feeding on this fish were in each period much lower than Holden's figure of 42%. This high frequency, however, may arise from one or more factors or from a combination of factors such as summer sampling at the height of the sand eel concentration, heavy local sampling of feeding fish within the region and possibly sampling in years of exceptionally heavy sand eel shoals resulting, for example, from successful recruitment. Whatever the explanation may be it is essential that the analysis of the food of any fish must be thoroughly representative of its distribution, and at the same time it must be spread over a sufficiently long period in order to eliminate possible bias caused by irregular, inadequate or seasonal sampling and natural fluctuations of both the stocks of the predator and those of its prey.

The analyses of dogfish food from the western Atlantic and Pacific also indicate local and seasonal sampling in some instances, but in general there is a remarkable similarity in the records from these two regions and the eastern Atlantic. In the first place it is clear that fish are the predominant food in each region, possibly, on average, to the extent of 75% of the total. Crustaceans and molluscs each provide an appreciable proportion of the stomach contents, although apparently in different ways. A number of investigators, for example, have found crustaceans forming a considerable part of the food locally or in individual samples. This was observed in the Scottish investigations in the Firth of Clyde, where *Meganyctiphanes* was commonly eaten on a number of occasions, and off the Lincolnshire coast, where *Eupagurus* and "shrimps" were prominent in the food in October 1921. On the coast of Newfoundland 42% of Templeman's dogfish had eaten amphipods, though not heavily, and off the coast of British Columbia dogfish had eaten "shrimps" in three localities, including the west coast of Vancouver Island, where more than half of the stomachs with recognisable food contained this food type. Off the coast of Washington State euphausiids were prominent in the stomachs in at least two of the 24 samples of dogfish.

In contrast to the variations in the frequency and in the types of crustaceans identified in the food, molluscs were represented more evenly, and predominantly by one class, the cephalopods. In Scottish waters these were represented in 11% and 10% of the stomachs by at least 4 genera, *Eledone, Loligo, Sepiola* and *Rossia,* and Holden found squid and octopus eaten by 12% of the dogfish in his samples. These types have also been identified by other investigators, and all the analyses agree that other molluscan animals, such as lamellibranchs and gasteropods, are rarely eaten by spurdogs.

As already observed, a number of planktonic types were identified in the food of dogfish in Scottish waters. These include salps, *Pleurobrachia* and the jellyfish *Chrysaora*. Holden recorded the ctenophore *Beroe* once from off the north of Scotland. Reference has already been made to the heavy predation on *Pleurobrachia* recorded by Todd on at least one occasion in the southern North Sea in June. In addition to the Scottish records of *Chrysaora*, jellyfish were also identified in two stomachs off Newfoundland (*Aurelia aurita*) and on four occasions in one sample off the coast of Washington (*Cyanea capellata*).

Other types identified rather less frequently by one or more of the investigators of dogfish food include annelids, gephyreans, echinoderms, anthozoans, sponges, seaweed and eel grass (*Zostera marina*), but these must be regarded as being of minor importance in the diet of the spurdog.

From time to time unusual items have been identified in spurdog stomachs. These include mammalian

flesh, twice by Holden and once in the present Scottish studies, which would appear to be seal or porpoise. Although the possibility of dogfishes attacking or killing a healthy seal or porpoise cannot be entirely disregarded, a more likely explanation may be that the fish had eaten a dead or sickly animal. This suggests a scavenging habit in the spurdog and support for such a view would seem to be provided by the 'oddities'—fat pork and the remains of a sea bird—found by Templeman in two stomachs off Newfoundland. Even more convincing evidence that dogfish act as scavengers, however, is provided by Fraser (1946) and Clemens and Wilby (1946)—see page 10.

Most of the published accounts of dogfish food refer to quantities of unrecognisable material in the stomachs. Moreover, the proportions of unidentified food vary, no doubt depending to some extent on the time and trouble taken in its examination. In some instances invertebrate material has simply been recorded under the heading "Invertebrates," so that this may possibly include unidentifiable food which, on the available evidence, could not be classified as being of vertebrate origin.

In addition to demonstrating the predominance of fish in the food of the spurdog, the Scottish investigations have also stressed the overall importance of pelagic types, among which the herring is the outstanding single species. Similar investigations, although perhaps somewhat local or seasonal, in other British waters, also stress the pelagic feeding habit of the spurdog and show that herring, sand eels, mackerel and pilchards together form a considerable proportion of its food. Other pelagic types, such as sprat, horse mackerel and argentine, are also eaten, and locally or seasonally semi-pelagic types such as cod, whiting, blue whiting, Norway pout and hake collectively appear to be preyed upon rather more frequently than are species with a more pronounced demersal habit such as haddock and the flatfishes. The spurdog's predation on these demersal fishes suggests that it feeds on the bottom from time to time, but this evidence is not entirely conclusive since haddock have been caught by floating lines and by mid-water trawl with planktonic food in their stomachs well off the sea bottom, and even flatfishes and other ground-keeping species such as *Lophius piscatorius* have occasionally been taken in trawls away from the bottom. However, it would seem from the capture of large quantities of spurdogs by otter trawl and by baited ground-lines that the species does feed demersally at certain times. The pelagic feeding habit of the spurdog in British waters is also stressed by the frequency with which certain planktonic invertebrate types occur in the food. These include cephalopods, euphausiids, coelenterates, ctenophores and tunicates.

These features are also evident in the food of the spurdog in the western Atlantic, where another pelagic fish, the capelin, *Mallotus villosus*, not a member of the British fish fauna, may seasonally represent an important item of food.

On the Pacific coast of America the fish and invertebrate populations are almost entirely different from those of the east and west Atlantic. It is perhaps noteworthy that the spurdog itself is one of the few species of fish common to all three areas. Nevertheless its food off the coast of British Columbia, as elsewhere, has been shown to consist largely of pelagic types. In some localities and at particular times of the year, a small pelagic fish, the eulachon, is heavily preyed upon by spurdogs as it enters the rivers to spawn. Throughout the rest of the year and in other localities the food is more variable but consists predominantly of pelagic types, including the Pacific herring, sand eels, hake, squid, shrimps and euphausiids.

Bonham has shown ratfish, *Hydrolagus colliei*, to be quantitatively the chief item in the food of the spurdog on the coast of Washington State. This observation is interesting in several respects. In the first place, the ratfish would appear to be the only individual demersal species in all the accounts of spurdog food to form any appreciable part of the total food. At the same time it should be noted that the ratfish occurred in only 44 of the 640 stomachs containing food, whereas herring and euphausiids, the next types in importance volumetrically, occurred in 115 and 135 of the stomachs respectively. It is also interesting that although the ratfish is very common along the whole coast of British Columbia (Clemens and Wilby, 1946) neither Fraser nor Chatwin and Forrester found it in any of the dogfish they examined.

This would seem to indicate that Bonham's results may reflect regional or local feeding, but his sampling covered both oceanic and coastal waters and ratfish were identified in one or more stomachs in 10 of his 24 samples, thus refuting to some extent the possibility of any local effect. Yet another curious feature of this predation is that *Hydrolagus colliei* may attain a length of over 3 ft and is thus comparable in size with most of the spurdogs in British waters. According to Clemens and Wilby, however, *Squalus suckleyi* (*acanthias*) can

attain a length of 5 ft 3 in. in the eastern Pacific so that at this size it could prey more easily on fully grown *Hydrolagus*.

Further reference to Bonham's paper shows that on the evidence available *Hydrolagus* was eaten mainly by dogfish in the upper section of the size-range, that is, from 100 to 125 cm. Moreover, most of the pregnant females which he examined fell into this size-group and 58% of the total volume of *Hydrolagus* from all the stomachs was found in these large females, averaging 105 cm in length. Of the remaining 42%, 26% were found in male dogfish averaging 80 cm in length, and 60% in non-pregnant females averaging 74 cm. It is evident, therefore, that predation on ratfish is mainly by the larger dogfish, and since the stomachs of these fish are likely to contain larger quantities of food than those of the smaller fish, it would appear that the volumetric analysis of the food tends to overstress the importance of this fish in the diet of the spurdog stock as a whole. This consideration of dogfish predation on *Hydrolagus* disregards the possibility of the latter fish leading a temporary pelagic existence at some stage in its life, but even so, Bonham's analysis still would appear to emphasise the pelagic feeding of the spurdog on the Washington coast. This is evident in the frequency with which the Pacific herring and other clupeoids, euphausiids, hake and cephalopods appear in the stomachs and the inclusion in the diet, though less frequently, of sand eels, king salmon, dog salmon, anchovy, young *Squalus*, smelt and jellyfish. Yet another feature of the food in British waters, namely the spasmodic appearance of certain planktonic types, is also evident in this area. For example, 99 of the 132 dogfish feeding on krill (euphausiids) were from one sample of 120 dogfish in which this food type provided 93% of the volume. Similarly, all four dogfish feeding on jellyfish were from a single sample of 18 fish in which jellyfish formed 43% of the total volume of food in the stomachs.

The spurdog has been termed an 'indiscriminate' or 'opportunist' feeder by some investigators of its food. The analyses of its stomach contents in each region have certainly shown that its diet comprises a very varied list of organisms, but this is equally true of many of our common fishes, both of widespread species such as cod (Rae, 1967), haddock (Ritchie, 1937), and whiting (Jones, 1954) and even of species of more restricted distribution and habitat such as the lemon sole and megrim (Rae, 1956, 1963). It has been shown in the Scottish investigations that the spurdog is primarily a pelagic feeder, evidently with a preference for pelagic fish. Even though it may be primarily dependent on these seasonal shoaling species, it seems probable that in the absence of its customary food the spurdog has, from time to time, to turn to other types. Leading a pelagic existence, it would seem natural that it should prey on planktonic invertebrate types when these occur in sufficient concentration to attract the dogfish shoals. Alternatively, it would also seem natural for the dogfish, during periods of scarcity of its pelagic food, to quit the upper water layers and to prey on near-demersal or demersal types such as the gadoids, flatfishes and benthic invertebrates. In Scottish waters most of the common commercially important fishes appear to feed on animals of many kinds, but at the same time to depend for the bulk of their food on a relatively small number of species or genera. The terms 'indiscriminate' and 'opportunist' would, therefore, scarcely appear appropriate when applied to cod, haddock, lemon sole or dogfish, although reliable estimates of discrimination will not be obtained until reliable and contemporary data of 'available' food can be compared with food 'eaten' as distinct from 'stomach contents'.

At this point it is opportune to consider the changes in the frequencies with which certain food types have been eaten by the spurdog from the period 1921–1939 to that of 1949–1966. The most obvious changes are first the decline in the proportion containing clupeoids (mainly herring) from 30% between the wars to 14% after the second war. This decline is accompanied by the doubling of the proportion of dogfishes eating mackerel, but the numbers preying on sand eels would seem to remain about the same. The second major change in the food is the marked increase in the proportions feeding on gadoids, from 4% between the wars to about 20% in the postwar period. These changes might be interpreted as indicating a growing scarcity of herring locally and, in consequence, an increasing predation on gadoids and other truly demersal types. Adult herring are certainly much scarcer than formerly on certain Scottish grounds, notably in the Moray Firth, off the Aberdeenshire coast (see Appendix) and possibly off the north of Scotland, which, though scarcely comparable in importance with the first two areas and other notable herring-fishing grounds, nevertheless used to give rise to substantial catches of herrings at certain seasons. In this area of heavy dogfish concentrations predation on herring has declined from 27 to 5% while that on gadoids has increased from 6 to 16%. Despite the local trend indicated by these results, however, it is scarcely justifiable to attempt to reach any definite

conclusion on the basis of the somewhat limited evidence available; moreover the general decline in dogfish stocks in recent years is also a factor which must be taken into account.

SUMMARY

This analysis of the food of the dogfish, *Squalus acanthias*, in the North Sea and on west of Scotland grounds, is based on observations carried out on Scottish research vessels from 1921 to 1939 and 1949 to 1966. Although it has been impossible to estimate the proportions feeding during the first period, the records show a high proportion (60%) with empty stomachs for 1949–1966.

The food consists primarily of fish; crustaceans and molluscs are eaten fairly commonly, while tunicates, annelids, coelenterates and ctenophores are taken less frequently and somewhat spasmodically. Quantities of unrecognisable material were also found in stomachs which may possibly indicate a somewhat greater predation on planktonic types than the identifiable items would suggest.

The food is also predominantly pelagic in character. The herring is the outstanding single species and, along with sand eels and mackerel, and semi-pelagic types such as whiting and *Gadus esmarkii*, forms the bulk of the food. Predation on pelagic invertebrates such as euphausiids, cephalopods, ctenophores, coelenterates and salps also emphasises the pelagic feeding habit of the spurdog. There is some evidence of a decline in the predation on herring and an increase in that on gadoids and other demersal species in certain localities from 1921–1939 to 1949–1966.

The food of the spurdog in the western Atlantic and the Pacific bears a close resemblance to the food in British waters in its general character, although not always in the individual types preyed upon.

Evidence from commercial sources (see Appendix) reveals considerable damage to fisheries, particularly herring fisheries, over a period of nearly 200 years.

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APPENDIX

REVIEW OF EVIDENCE FROM COMMERCIAL FISHERIES

The spurdog has long been regarded as an undesirable species by Scottish fishermen. This view has been based mainly on experience of the extensive damage caused by dogfish shoals to the various fisheries and to some extent also on its relatively insignificant market value in Scotland. In the light of the present food studies it is of interest to consider the origins of this reputation.

The first published record of the association of dogfish and herring shoals is contained in "The Statistical Account of Scotland" (1791). The writer of the chapter on the parish of Gamrie, Banffshire, after detailing the variety of fish caught on the coast, concluded thus:— "Of late years, fishing has been so remarkably poor (to which cause it is perhaps difficult to say, but most likely one principal reason is the immense quantities of sea-dogs, a kind of shark, with which this coast has been infested), that there has hardly been fish sufficient to supply the markets at home".

More than fifty years later, in "The New Statistical Account of Scotland" (1845), the author of the chapter on Rathven Parish, Banffshire, referred to the abundance of herring and to "sea-dogs, accompanying the shoals of herring, which were used as manure". The description of Banff Parish mentioned "common dogfish (*Spinax acanthias*) caught in increasing quantities during the herring season, mid-July to mid-September, and sold by the cart load for manure to the ground". In yet another chapter, on the Parish of Lonmay in Aberdeenshire, the writer stated—"Shoals of dogfish are seen during the herring season".

From these sources of information it is clear that the fishermen of Banffshire and Aberdeenshire suffered considerable hardships from the destructive habits of the spurdog, or common dogfish as it is generally known in Scotland. It is evident too that the alleged damage was much greater in some years than in others, depending partly, no doubt, on whether the herring shoals were first located by the fishermen or by the dogfish and partly on the size and extent of the dogfish invasion. It must also be borne in mind that at the time of these reports the fishery was conducted from open boats, powered by sail or oars, and that necessarily the grounds fished were more or less restricted to coastal waters. This made it almost impossible for the fishermen to seek other grounds in the event of a dogfish invasion of their local waters. In years of particular hardship there is even evidence that the local people were reduced to eating dogfish instead of their normal fish diet.

In the tenth annual report of the Fishery Board for Scotland (1892) Robert Duthie, Assistant Fishery Officer, wrote—"The greatest hindrance to the success of the herring fishing about Shetland has hitherto been the visits to these shores of large shoals of dogfish, that come with almost annual regularity. They always appear first on the west side of the islands, and as a rule gradually spread round the north and east coasts. Various theories have been put forward in explanation of their visits. A very plausible one is, that they come along in the course of the gulf stream till they meet the western coasts of the British Isles; and that this is why the fishing grounds about the Outer Hebrides, Orkney, and Shetland are so often overrun by them. Some seasons they seem to approach Shetland from the deep water to the northwest of Unst and Yell; at other times they appear first about Orkney and the progress of the shoal north-westwards may then be clearly traced by fishermen, and their arrival anticipated.

"The spring cod and ling fishing suffers at times from their ravages, but their visits are most frequent during the early herring fishing in June and July—just when they are least welcome. They are often so plentiful at that season that fishermen may sail for miles and find the sea swarming with them everywhere. It has now come to be understood that if dogfish appear in large numbers on the coast, fishermen will be allowed to get quit of their engagements and leave the district, as persistent fishing in such circumstances would only ruin them without doing any good to the curers.

"As the summer advances the shoal often spreads southwards along the east side of the islands, and becomes equally troublesome during the autumn herring fishing, of which Lerwick is the centre.

"From the fact that winter fishing is confined pretty much to land-locked waters in Shetland, the movements of the dogfish shoals are not so clearly defined after the close of the herring fishing. It is believed that some seasons they remain off and on about the islands all the year round; but usually they disappear from the coast when the cold weather sets in, very few being seen by the haddock fishers."

Dogfish predation on fish stocks in Scottish waters continued to cause annoyance and damage after the first war. In 1925, Dr A. Bowman, Scientific Superintendent of the Marine Laboratory, replied to an enquiry thus—"Dogfish sometimes occur in such numbers on the fishing grounds that they become a source of annoyance to the fishermen. When numerous on the herring fishing grounds they may cause considerable damage not only to the herrings out of the backs of which they take large bites but also to the drift nets in which they may get entangled when seeking the herring. They do not mesh in the drift nets, but only come to the upper water layers after the herring.

"Dogfish are also caught on great lines and by trawl, but the fishermen studiously avoid those grounds where they are abundant. In the case of the great line fishing the dogfish readily take the hooks baited with herring and if present on a fishing ground in numbers they reduce considerably the chances of capture of more valuable fish. When dogfish become too numerous the fishermen seek other grounds."

Later Dr Bowman referred to the damage to trawl catches of more valuable fish when he added—"the sharp dorsal spines pierce the fish and the rough skins completely denude the haddocks of their scales".

In the 1930s damage by dogfish to fisheries continued to be reported by Scottish fishery officers. These reports refer to the mutilation of herring gilled in drift-nets, when frequently only the head or anterior portion of the individual herrings were left in the net, and less frequently to torn drift-nets. Numerous accounts were also given of trawlers being

forced to change grounds when dogfish appeared to disrupt the shoals of more desirable demersal fish or to spoil the appearance of the catch.

Mr James Reid, a herring fisherman of the inter-war period, has stated that although dogfish damage to herring catches was generally most severe and most frequent in Shetland waters, he personally had also encountered this problem on other east coast grounds in the 1920s, once at a position 80 miles ESE of Peterhead on the Aberdeenshire or Buchan grounds and on another occasion off East Anglia.

He had also experienced similar damage in the Minch near the Butt of Lewis and once as far south as the Isle of Man in the Irish Sea, although in this area the predator, from the information given, would appear to have been the tope, *Eugaleus galeus* (L.)—an experience which has since been confirmed by another Scottish skipper at a later date.

Between the wars it was customary for Peterhead fishermen to fish with lines on the Viking Bank during the spring, in the interval between drift-net fisheries. Mr Reid, who took part in this fishery, has stated that the bait was often taken by dogfish, and not infrequently the catch, consisting of cod, ling, halibut and skate, was bitten and mutilated by these fish. Mr Reid also made the interesting observation that damage by dogfish to herring gilled in drift-nets usually appeared to be most severe during stream tides and that catches of herring were usually relatively free from damage at slack tidal periods.

After the second war dogfish continued to be troublesome to Scottish fishermen. Following a cruise by the Scottish research vessel "Clupea" off the Aberdeenshire coast in June 1948, the scientist in charge reported that without doubt the continuous harassing of herring shoals by dogfish had contributed to the poverty of the herring catches in that month.

In 1956, following persistent damage to catches at Shetland, representations were addressed to the Scottish Office with a suggestion that the catching of dogfish should be encouraged in some way, possibly by the payment of a bounty, with a view to improving the catches of other commercial species by reducing the numbers of predators. No action was taken since the proposal was considered impracticable.

A small fishery, employing set ground-nets, for cod, hake, lythe etc. in the narrow waters of the Minch during the winter and spring has frequently suffered from the ravages of dogfish. This fishery has also suffered from the activities of seals but it is possible to distinguish between the harm caused by the two predators from the nature of the damage to the fish gilled in the nets. Dogfish bites are smaller and fairly clear-cut compared with the bigger and ragged, tearing bites of the seals. Moreover, the dogfish appear to bite any part of its prey, though more frequently the fish's back, while the seal almost invariably removes the whole or most of the belly region, including the roe or milt and the liver. The identification of the predator is also simplified by the occasional entanglement of the seal or dogfish in the net.

Yet another instance of spurdog predation on fisheries was reported by Mr S. F. Pirie, a member of the laboratory staff, in October 1958. Mr Pirie accompanied a small-line vessel fishing for haddocks in Broad Bay, Lewis, for the purpose of tagging lively fish. On hauling the lines, many of the haddocks on the hooks of certain sections of the line were found to have been bitten by dogfish, often with the head alone remaining.

So far no precise damage to seine-net catches appears to have been reported in Scotland, but dogfish shoals certainly constitute a nuisance to seiners in some areas. The Inspector of Sea Fisheries for the Scottish North-western District, for example, reported in December 1965 that fishermen (seine-net and light trawl) fishing in the North Minch were being troubled by large shoals of dogfish in so far as their catches consisted of large quantities of these fish to the exclusion of more profitable types, and that the appearance of good quality fish in the catches was being spoiled by contact with the dogfish.

This short review of the evidence of dogfish predation from commercial sources has revealed records of damage over a period of nearly 200 years. It seems clear that the drift-net fishery for herring suffered most heavily throughout this period, although nearly every fishery for demersal fish has also been affected in some measure.

The evidence also indicates the variable strength of the annual invasion of the North Sea by spurdogs. From the earliest accounts in the first and second Statistical Accounts the concentrations of these fish in the coastal waters of Banffshire and Aberdeenshire would appear to have been much greater than any experienced in these waters since routine investigations were started by research vessels more than fifty years ago. This may reflect a decline in the numbers of dogfish entering the North Sea annually from their main population centres to the north and west of Scotland and the northern isles. However, the south-eastern Moray Firth, which initially gave rise to the herring catches on which the great Scottish herring fishery was built up during the last century and which in the early inter-war period still provided good catches, now yields much smaller quantities of herring. Consequently the almost complete absence of dogfish from the Moray Firth grounds may be owing to the scarcity of herring in these waters.

During 1966 fishermen were asked, either directly or through fishery officers, for information about dogfish depredations throughout the year. Without exception the replies received suggest that little or no damage was sustained by the herring drift-net fishery on any of the fishing grounds, nor indeed could any substantial damage to herring be recalled in the preceding two or three years. This would seem to suggest a decline in dogfish predations, but it seems inevitable that with the marked decline in the herring fisheries the number of incidents of dogfish damage will also be fewer.

Nevertheless, dense concentrations of dogfish continue to be located on north-western grounds by research vessels and by commercial fleets—for example, in the North Minch in December 1965. Furthermore, Aberdeen trawlers fishing on Turbot Bank, east of the Aberdeenshire coast, in July 1966, reported a very dense concentration of spurdogs which extended from 40 to 70 miles eastwards from the coast. Catches of up to 40 or 50 baskets of dogfish per haul were taken on board over a number of days, and on at least one occasion a catch was lost through the bursting of the cod-end. In contrast to fishing experience in recent years dogfish continued to be plentiful in catches off the Aberdeenshire coast

and to the south of Aberdeen as late as December 1966. Although this dogfish concentration was considered exceptional by the younger skippers, the older fishermen, particularly those with a knowledge of drifting, readily recalled earlier occurrences of a similar nature. Despite the decline in the numbers of dogfish caught in Scottish waters and the apparent decline in the numbers now invading the North Sea, the shoals located on Turbot Bank in July show that the annual invasions still take place.

Elsewhere (Rae, 1961), it has been suggested that the dogfish invasion of North Sea grounds, beginning in May and continuing well into the last quarter of the year, is a feeding migration, and that since the herring is the commonest single species in the food of the spurdog it seems reasonable to assume a link between the movements of the dogfish shoals southwards and the successive concentrations of herring in the western half of the North Sea. Holden (1966 b) found no support for this view in his results, based on enquiries made of fishermen in very recent years. Enquiries among Scottish skippers in 1966 confirm that dogfish damage has been negligible of late, but one cannot ignore the information from earlier years summarised in the present review.

A study of the food and movements of other members of the shark family shows that several species invade the North Sea or western coastal grounds every year on what would appear to be feeding migrations. The movements of the plankton-feeding basking shark, for example, are already well known, but perhaps the most obvious of the others is the porbeagle, which, like the spurdog, begins to appear on the Shetland herring fishing grounds in May and thereafter progresses southwards to the Aberdeenshire herring grounds in June, July and August, before finally reaching coastal waters in the Moray Firth and East Scottish Bight in the last quarter of the year. Herring and other clupeoids and squid are dominant types in the porbeagle's food, which also includes demersal species. Another immigrant to the North Sea is the tunny which also preys heavily on herring, on the Fladen and other grounds, from July to October, so that the conception of a dogfish migration into the North Sea for the purpose of feeding on herring shoals is not without parallel in other species.

Dogfish predation on fish stocks and its consequent effect on fisheries, however, is not confined to British waters. Templeman (1944) refers to the harm caused by *Squalus acanthias* to fisheries off Newfoundland thus—" . . . an abundance of dogfish affects unfavourably every other fishery, particularly net fisheries such as salmon. . . .". He also refers to observations by Bigelow and Welsh (1925) that—"dogfish are estimated to do no less than 400,000 dollars' worth of damage annually to fishing gear and to fish caught by such gear off the Massachusetts coast alone and probably no less on the shores of Maine". Templeman also quotes Bigelow and Welsh thus—"not only does it (*Squalus*) harry and drive off mackerel, herring and even fish as large as cod and haddock but it destroys vast numbers of them". Dogfish shoals have presented similar problems to fisheries on the west coast of America. Jensen (1966) concluded his assessment of the market value of the dogfish in the United States thus—"Management of the species is indicated to reduce the damage it causes to more valuable commercial fisheries. Finding an economically attractive use for the dogfish would be the most worthwhile management method. Lacking this, perhaps some form of biological control must be instituted."

This review of the damage caused to Scottish fisheries by dogfish explains to a considerable extent the antipathy of Scottish fishermen towards this fish. Undoubtedly, too, the poor prices which have prevailed on the Scottish market in the past have also contributed to the lack of interest in fishing for dogfish. Although the growing scarcity on the English market and the improvement in the market value in Scotland in recent years have possibly aroused greater Scottish interest in the dogfish, it seems clear that the decline in the stocks of this predator on other commercially important fish over the last five years is not regretted in Scotland.

The value of a fishery for any particular species varies from one nation to another. Although the dogfish has not hitherto been held in high esteem in Scotland, it is recognised that other nations may regard it as of much greater importance and may consider its conservation desirable. Accordingly, any decision to conserve dogfish stocks must first of all be preceded by a comparison of the harm caused by the stocks of dogfish to other fisheries with the value of dogfish landings by themselves. On the evidence of this review the damage to other fisheries in Scotland would seem to outweigh the value of the dogfish catch, but it must also be borne in mind that the rise in the average price of dogfish on the Scottish market in recent years may well affect the relative economic importance of this fish in future years.

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